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NEST-SITE SELECTION OF THE CROWNED HAWK-EAGLE IN THE FORESTS OF KWAZULU-NATAL, SOUTH AFRICA, AND TAÏ, IVORY COAST

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ABSTRACT.—Structural characteristics of Crowned Hawk-Eagle (*Stephanoaetus coronatus*) nest sites were compared between forests in KwaZulu-Natal province, South Africa, and the Taï National Park, Ivory Coast, and key features of nesting trees and nest-placement sites were identified. Nest-tree heights and nest heights differed appreciably between three tree groups with the highest being indigenous Taï trees ($\bar{x}$ tree height = 52 m and $\bar{x}$ nest height = 36 m, N = 8 nests), followed by exotic eucalyptus ($\bar{x}$ = 44 and 22 m respectively, N = 10) and indigenous trees ($\bar{x}$ = 24 and 14 m respectively, N = 17) from KwaZulu-Natal. All the nest trees in Taï were emergents, whereas 11 of 17 indigenous nest trees and only two of 10 eucalyptus were so in KwaZulu-Natal. Non-emergent eucalyptus nest trees were predominantly edge trees that may have provided easier access for flying eagles. Overall, nest forks were more accessible for flying eagles than random forks, although access did not differ between nests located in emergent and non-emergent trees. Crowned Hawk-Eagles transport long sticks and heavy prey items to their nests and access was probably the most critical feature of both the nest tree and placement of the nest. Wildlife managers must, therefore, ensure that lone-standing or emergent trees are cultivated and conserved, and flight paths to nests are kept open to allow Crowned Hawk-Eagles continued and easy access to their nests.

KEY WORDS: *Crowned Hawk-Eagle;* Stephanoaetus coronatus; *nest access; emergent trees; nest-site selection; wildlife management.*

SELECCIÓN DEL SITIO NIDO DEL AGUILA CORONADA EN LOS BOSQUES DE KWAZULU-NATAL, SUR AFRICA, Y TAÏ, COSTA DE MARFIL

RESUMEN.—Las características estructurales de los sitios nido de las águilas coronadas (*Stephanoaetus coronatus*) fueron comparadas entre los bosques de la provincia KwaZulu-Natal, Sur África, y el parque nacional Taï, Costa de Marfil, y se identificaron los rasgos claves de los árboles nido y de los sitios de ubicación de los nidos. Las alturas de los árboles nido y las alturas de los nidos difirieron apreciablemente entre árbol y grupo de árboles siendo los más altos los nativos Tai ($\bar{x}$ altura del árbol = 52 m y $\bar{x}$ altura del nido = 36 m, N = 8 nidos), seguido por eucaliptos exóticos ($\bar{x}$ = 44 y 22 m respectivamente, N = 10) y árboles nativos ($\bar{x}$ = 24 y 14 m respectivamente, N = 17) de KwaZulu-Natal. Los arboles nido de eucaliptos no emergentes fueron predominantemente árboles de borde que podían proveer más fácil acceso a las águilas en vuelo. En conjunto, las horquetas en nidos fueron más accesibles para las águilas que horquetas colocadas al azar, aunque el acceso no difirió entre los nidos colocados en árboles emergentes y no emergentes. Las águilas coronadas transportan grandes ramas y presas pesadas a sus nidos y probablemente el acceso fue el rasgo mas critico tanto para la selección del árbol nido como para la ubicación del nido. Los manejadores de vida silvestre deben, por lo tanto, asegurar que árboles aislados o emergentes son cultivados y conservados, y que las vías de vuelo a esos nidos permaneceran abiertas para permitir a las águilas coronadas continuo y fácil acceso a sus nidos.

[Traducción de César Márquez]

Tree-nesting raptors select nesting trees and nest sites on the basis of certain structural features that hide the nest from potential predators, insulate the nest against adverse weather conditions, place the birds close to their hunting habitats and allow them easy access to the nest (Moore and Henny 1983, Speiser and Bosakowski 1987, Lilieholm et al. 1993, Burton et al. 1994, Selas 1996, Malan and

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Robinson 2001). Larger raptors often nest in an exposed position that allows easy access to and from the nest to deliver long sticks and heavy prey (Speiser and Bosakowski 1987, Burton et al. 1994). To further facilitate access, large raptors nest in tall emergent trees or large trees with open branch structures that respectively allow them access to the nest both above and within the canopy (Moore and Henny 1983, Burton et al. 1994, Malan and Robinson 2001). Unfortunately, these preferences bring large eagles in direct conflict with man as large trees often are selectively harvested for commercial and subsistence purposes (Bijleveld 1974, Watson and Rabarisoa 2000).

In the predominantly arid South Africa, the depletion of indigenous forest habitats and the arrival of commercial exotic *Eucalyptus, Pinus, Acacia,* and *Populus* trees have had a mixed impact on the abundance and distribution of tree-nesting forest birds (Low and Rebelo 1996, Allan et al. 1997). Although by 1997 the area under commercial pulpwood and sawlog plantations (15 186 km^2) was four times larger than the existing natural forests (Van der Zel 1996, Anon. 1998), the very short rotation intervals of plantations (8–16 yr) do not allow the trees to attain the size necessary to support large stick nests. However, isolated, non-commercial stands of large exotic trees are used for nesting by indigenous birds, including raptors (Steyn 1977, Macdonald 1986, Malan and Robinson 2001). In indigenous forests, the processes of deforestation, forest fragmentation, and the selective removal of big trees from remnant patches alter the size, structure, and availability of indigenous trees for nesting (Tarboton and Allan 1984, Allan and Tarboton 1985, Seydack 1995, Vermeulen 1999).

In South Africa, the Crowned Hawk-Eagle (*Stephanoaetus coronatus*) has recently become of formal conservation concern and the status of the species has changed to near threatened due to the loss of its previously suitable, indigenous nesting habitat to short rotation, exotic plantations (Barnes 2000). Throughout much of its range, the Crowned Hawk-Eagle breeds in tall evergreen forests but can also nest in deciduous forests and woodland-forest mosaics (Tarboton and Allan 1984). These birds prefer large forest trees for nesting and the nest is usually situated in a major fork, 8–30 m above ground but can be as high as 46 m (Steyn 1982, Tarboton and Allan 1984, Brown and Amadon 1989). In South Africa, Crowned Hawk-Eagles nest in exotic eucalyptus and pines, in addition to indigenous trees, consisting of mostly White Stinkwoods (*Celtis africana*) (Tarboton and Allan 1984, Boshoff 1988).

The objective of this study was to compare Crowned Hawk-Eagle nesting sites in three tree groups and to use this information to provide resource managers with silvicultural guidelines for providing nest-placement sites and stands for Crowned Hawk-Eagles. As the forests in the KwaZulu-Natal province, South Africa, are relatively small in size and patchy in distribution (Boshoff 1997, Midgley et al. 1997), nest site characteristics of these forests were compared with those from the extensive and continuous, indigenous forest of the Taï National Park, Ivory Coast. These comparisons clarify which structural features are most important when selecting a nest site, and how flexible Crowned Hawk-Eagles are with regard to these characteristics. Second, for KwaZulu-Natal, we examine stand size to determine the minimal habitat requirements and compare topographical features with randomly-selected sites to determine the eagle's selectivity for these features.

Study Areas

In South Africa, Crowned Hawk-Eagle nest sites were located for study during forest surveys in the KwaZulu-Natal (29°S, 31°E). Indigenous tree stands were surveyed in forests characterized by a 10–25 m high canopy, distinct vegetation strata and numerous dominant tree species (Low and Rebelo 1996, Midgley et al. 1997). The mean annual rainfall in these forests range from 900–1500 mm. Indigenous nest trees were sampled in the Oribi Gorge, Vernon Crookes, Krantzkloof, Harold Johnson, and Dlinza Forest nature reserves, Ithala Game Reserve, Hluhluwe-Umfolozi Park, all areas managed by the KwaZulu-Natal Wildlife, and the Umgeni Valley Nature Reserve and Tanglewood Natural Heritage Site. Exotic eucalyptus were surveyed in abandoned plantations, self-sown stands, and planted trees in large domestic gardens, but none were known from commercial sawlog or pulpwood plantations.

In the Ivory Coast, all nest sites were located within a 50 km^2 area around the Station de la Recherche en Ecologie Tropicale (SRET, 7°00′N, 5°50′W) near the western edge of the park. The Taï National Park is the largest continuous lowland forest in West Africa (454 000 ha) and contains the last sizeable protected habitat for a number of Upper Guinea Forest endemics (Gartshore et al. 1995). The mean annual rainfall at the research station is 1800 mm. The forest was selectively logged in the early 1970s, but the structure is essentially indistinguishable from a primary forest. The main forest canopy is 30–40 m in height, with emergent trees reaching to over 60 m (Guillaumet 1994).

Methods

The authors and conservation officers located 27 Crowned Hawk-Eagle nests in KwaZulu-Natal and eight in Taï. Of the nests in KwaZulu-Natal, 19 were found by listening for the loud *queee-queee* soliciting calls of nestlings or by spotting large nests (Steyn 1982). Although this non-systematic search method may bias the sample toward accessible and conspicuous nests (Daw et al. 1998), the nest-site data include nests from a wide selection of forest and nest-tree types. Sampled nest trees were located in indigenous forests, exotic monocultures, and mixed forests, and nest tree species were grouped into either indigenous or eucalyptus stands.

The following nest-tree characteristics were recorded from each nest site: the tree diameter at breast height (1.4 m, DBH) of all stems ≥22 cm in diameter; tree height (T), nest height (N), height of the first foliage, and the height of the first side branch (R, irrespective if it was dead or alive). All height measurements were taken with a clinometer. For trees with buttresses ($N = 3$), the circumference of the tree, including the buttresses, was measured at breast height, a diameter calculated and divided by two as to provide a conservative estimate of DBH. The percent nest height was the proportional distance the nest was placed from the top of the tree ((N/T)100) and the percent first branch height was the proportional height the first branch was placed from the top of the tree ((R/T)100).

Nests were classified as being placed within or below the foliage. Each nest was scored as either being positioned in a main fork, against the main branch (i.e., primary axis, mainly vertical), or on a side branch (i.e., secondary axes, mainly horizontal). The number of branches supporting the nest was also counted. Lastly, the nest tree was classified as emergent if the branch and foliage structure protruded above the surrounding forest.

For each nest tree, we identified large and open forks, excluding the nest fork, which could possibly support a Crowned Hawk-Eagle nest that was 2 m wide and 2.5 m deep (Steyn 1982). Each of these forks was categorized as being positioned in a central fork or crotch (i.e., between main branches), as against the main branch, or on a side branch, and numbered from tree bottom to top. A random fork was selected from the category of the fork that supported the nest (i.e., if the nest was against a main branch, the random fork was selected from similar forks). If the random fork was not available from the category that supported the nest, it was selected from a combined sample of the remaining two positions.

For each cardinal direction (N, E, S, and W), accessibility of the nests and random forks were determined by whether the flying eagle would have a 30 m unobstructed approach on a horizontal plane. For a flying eagle, a flight path to the nest obstructed by foliage and/or branches thus qualified inaccessibility.

We sampled characteristics of the three trees closest to the nest tree. The distance from the nest tree to each surrounding tree was measured. We calculated the mean area occupied by the trees by squaring the mean distance of the three trees from the nest tree. We then converted the result to the number of trees per hectare and calculated a tree density estimate at the nest tree (Phillips 1959).

For KwaZulu-Natal nest trees, each nest was plotted on a 1:10 000 orthophoto (black and white aerial photograph with 50 m contour lines) to calculate stand size and shape. From this photo, the maximum length (A) and maximum width (B; perpendicular to the maximum length axis) of the nest stand was measured. All measurements from 1:10 000 orthophotos were rounded to 10 m to allow for a 1 mm measurement error. Stand shape (S) was defined as the maximum stand width divided by the maximum length, with values ranging from one (square shape) to zero (elongated shape). Nest stand shapes were grouped into square (Shape ≥0.5) or elongated (Shape <0.5). The surface area of planted forests was calculated from orthophotos by measuring the stand lengths and widths. The surface area of indigenous forest stands could not be calculated from orthophotos because the edges of indigenous forests were not defined clearly and the surface area was, therefore, estimated as $S = (A/2)(B/2)(\pi)$. From the orthophotos, the nest trees were also categorized as being located on the edge of the stand (i.e., the first tree encountered on the edge of a forest stand). Lastly, distances to water, road, and nearest human habitation were measured from the nest tree and one random tree selected from each nest stand.

All data were subjected to the Kolmogorov-Smirnov one-sample test of normality. If the distribution of the data was found to be non-normal, the non-parametric Kruskal-Wallis test or Mann-Whitney U-test was employed. The Tukey honest significant difference test for unequal sample sizes was employed to determine which groups are particularly different from each other after a significant Kruskal-Wallis test was obtained from the Analysis of Variance. The Pearson's Chi-square test was used to test for patterns with categorical variables. All data were analyzed using the Statistica software package (StatSoft 1995) and probability levels were set at $\alpha = 0.05$.

RESULTS

Of the 35 Crowned Hawk-Eagle nests analyzed, 10 were located in eucalyptus and 17 in indigenous trees in KwaZulu-Natal, and eight in indigenous trees in Taï. Indigenous nest trees identified in KwaZulu-Natal included *Ficus* spp. (7), *Chrysophyllum viridifolium* (3), *Syzygium cordatum* (2), *Cussonia spicata, Schotia brachypetala,* and *Celtis africana.* The exotic nest trees were all eucalyptus. Nest trees identified in Taï included *Lofira alata, Klainodoxa gabonesis, Ceiba pentandra,* and *Alstonia boonei.*

All tree characteristics measured differed among the three tree groups (Table 1). Taï and eucalyptus nest trees were taller than KwaZulu-Natal's indigenous trees. Taï nest trees were larger in diameter, and had higher first foliage, side branches and percent first side branch heights than trees from KwaZulu-Natal. Nest heights differed among all three tree groups, and the percent nest heights were lower in eucalyptus than Taï nests (Table 1).

The number of branches that supported nests did not differ among tree groups (Kruskal-Wallis $H_{2,35} = 1.7$, $P = 0.41$), and the eagles used on av-

Table 1. Crowned Hawk-Eagle nest-tree characteristics of eucalyptus and indigenous tree groups in KwaZulu-Natal and Taï. Means ± one standard deviation and range in parenthesis. Values with the same superscripts indicate values that differed significantly from each other in the three-way comparison.

Species Class	Indigenous KwaZulu-Natal	Eucalyptus KwaZulu-Natal	Indigenous Taï	N	Kruskal-Wallis H
DBH (cm)	$93^{a} \pm 29$ (40–151)	$126^{b} \pm 32$ (83–206)	$234^{ab} \pm 66$ (167–344)	35	21.6**
Tree height (m)	$24^{ab} \pm 6$ (15–34)	$44^{a} \pm 8$ (34–54)	$52^{b} \pm 14$ (33–67)	35	25.7**
Height of first foliage (m)	$9^{a} \pm 6$ (1–19)	$12^{b} \pm 9$ (6–27)	$33^{ab} \pm 7$ (26–42)	35	17.8**
Height of first side branch (m)	$9^{a} \pm 6$ (1–20)	$15^{b} \pm 7$ (6–25)	$34^{b} \pm 9$ (25–47)	35	17.8**
Nest height (m)	$14^{ab} \pm 3$ (7–21)	$22^{ac} \pm 7$ (13–35)	$36^{bc} \pm 10$ (25–49)	35	23.4**
Percent nest height	58 ± 14 (43–93)	$52^{a} \pm 13$ (36–67)	$71^{a} \pm 13$ (44–90)	35	7.6*
Percent first side branch height	$36^{a} \pm 21$ (4–62)	$32^{b} \pm 12$ (16–47)	$66^{ab} \pm 13$ (44–78)	35	14.3**

^{abc} = all $P < 0.05$, Tukey tests.
* $P < 0.05$.
** $P < 0.001$.

erage 3 ± 1 branches ($\bar{x} \pm$ SD, N = 35 trees) to nest on. Twenty-seven of 32 nests (84%) were placed within the foliage (as opposed to under the foliage), and placement of nests in relation to the foliage was not associated with tree groups (χ^2 = 0.7, P = 0.70). In Taï, 63% of the nests (N = 8) were placed on the lowest side branch, more frequently than nests in indigenous (13%, N = 17) and eucalyptus trees in KwaZulu-Natal (10%, N = 10, χ^2 = 9.3, $P < 0.01$).

Of the 35 nests sampled, 20 (57%) were placed in a central fork, nine (26%) on a side branch, and six (17%) against the main branch; nest placement was not associated with tree groups (χ^2 = 6.3; P = 0.17). Whereas seven (78%) of the nine side-branch nests and four (67%) of the six main-branch nests were from the most abundant fork category, 18 (90%) of the 20 central-crotch nests were from trees where this fork type was not the most abundant (χ^2 = 6.3; $P < 0.001$). Overall, 22 (63%) of the 35 nests were not placed in the most abundant fork category and nest placement could not be associated with the most abundant fork category of the different tree groups (χ^2 = 1.0; P = 0.59).

The number of forks per nest tree did not differ among the tree groups (11 ± 6 forks in indigenous KwaZulu-Natal trees, 14 ± 8 in eucalyptus, and 7 ± 3 in Taï nest trees; Kruskal-Wallis $H_{2,35}$ = 3.4, P = 0.16). Whereas the number of central forks per tree did not differ among tree groups (1 ± 1, Kruskal-Wallis $H_{2,35}$ = 3.2, P = 0.21), the number of side forks did (indigenous KwaZulu-Natal 5 ± 4 forks, eucalyptus 2 ± 2, and indigenous Taï 3 ± 3; Kruskal-Wallis $H_{2,35}$ = 6.2, $P < 0.05$), although the classes were not significantly different from each other (Tukey tests, all $P > 0.05$). Eucalyptus had more forks against the main branch (11 ± 8) than indigenous trees in KwaZulu-Natal (4 ± 3) and Taï (3 ± 1; Kruskal-Wallis $H_{2,35}$ = 9.6, $P < 0.01$; Tukey tests, all $P < 0.05$).

All the nest trees in Taï and 11 of 17 indigenous nest trees in KwaZulu-Natal were emergents, whereas only two of 10 eucalyptus protruded above the forest canopy (χ^2 = 12.2, $P < 0.05$; Table 2). Overall, nests were more accessible to flying eagles

Table 2. The emergence of Crowned Hawk-Eagle nest trees above the surrounding forest.

Emergent Nest Trees	Yes	No	Total
Indigenous—KwaZulu-Natal	11	6	17
Eucalyptus—KwaZulu-Natal	2	8	10
Indigenous—Taï	8	0	8
Total (Percent)	21 (60)	14 (40)	35

Table 3. The number of Crowned Hawk-Eagle nest trees, with flight paths sampled in four cardinal directions, which allowed access to nest and random forks for 17 indigenous and 10 eucalyptus trees in KwaZulu-Natal, and eight indigenous trees in the Taï Forest.

NUMBER OF FLIGHT PATHS	NONE	ONE	TWO	THREE	FOUR	χ^2
Nest fork	0	1	12	12	10	
Random fork	4	12	8	4	7	18.6**

** $P < 0.001$.

Table 4. The number of flight paths per Crowned Hawk-Eagle nest tree, sampled in four directions, which allowed access to nest forks in emergent and non-emergent trees.

NUMBER OF FLIGHT PATHS	NONE	ONE	TWO	THREE	FOUR	TOTAL	χ^2
Emergent	0	0	5	7	9	21	
Non-emergent	0	1	5	3	5	14	2.4

than were random forks (Table 3). Access to nests could not be associated with their placement above (as emergents) or within the forest canopy (Table 4). In KwaZulu-Natal, seven of the eight non-emergent eucalyptus were located on the edge of the nest stand, whereas, all the non-emergent indigenous trees were located inside the nest stands ($\chi^2 = 7.3$, $P < 0.01$).

The mean distance from the nest tree to the nearest three trees did not differ among tree groups (indigenous KwaZulu-Natal 11 ± 6 m, eucalyptus 12 ± 8 m, and indigenous Taï 13 ± 5 m; Kruskal-Wallis $H_{2,34} = 1.0$, $P = 0.62$). The density of trees at nest sites also did not differ among tree groups (all trees 156 ± 175 trees/ha, indigenous KwaZulu-Natal 172 ± 183 trees/ha, eucalyptus 189 ± 219 trees/ha, and indigenous Taï 85 ± 62 trees/ha; Kruskal-Wallis $H_{2,34} = 1.0$, $P = 0.62$).

The areas of 13 Crowned Hawk-Eagle nest stands in KwaZulu-Natal were not normally distributed and were predominantly less than 50 ha in size (Table 5). Nest stands were primarily small (20 m in width and 30–50 m in length) and elongated in shape (shape-index <0.5; Table 5). Shape-index values could not be associated with eucalyptus and indigenous tree stands ($\chi^2 = 0.12$, $P = 0.73$).

Nest and random tree distances to topographical features were not different for all variables when comparing means (Table 6) and Crowned Hawk-Eagles were, therefore, non-selective regarding these topographical features. One tree selected for nesting was 20 m from an inhabited brick house and another 10 m from a used bitumen road.

DISCUSSION

Nest-site Selection. Tree-nesting raptors assess variables such as vulnerability to predators, protection against adverse weather conditions, the cost of nest building, structural features of the nest tree, and access to the nest when selecting a site to build their nest (Newton 1979, Moore and Henny 1983, Bosakowski and Speiser 1994, Burton et al. 1994). Whilst smaller raptors regularly conceal their nests to avoid predation, larger raptors are less secretive and customarily put their nests in exposed positions (Speiser and Bosakowski 1987, Selas 1996). The large, 2–2.5 m wide and 2.5–3 m deep nests of the Crowned Hawk-Eagle (Steyn 1982) are very conspicuous.

Although large raptors generally do not hide their nests as they can defend their nestling against predators (Moore and Henny 1983), Crowned Hawk-Eagles do suffer some nest predation from primates, especially if the nest tree can be accessed

Table 5. Statistical distribution of KwaZulu-Natal Crowned Hawk-Eagle nest-stand variables and shape index with the Kolmogorov-Smirnov distribution test (K-S d) for normality.

	DOMINANT CATEGORY (PERCENT)	MEAN ± 1 SD	RANGE	N	K-S d
Surface area (ha)	0–50 (77)	35.4 ± 73.7	0.05–250.15	13	0.42*
Maximum width (m)	20 (69)	253 ± 363	20–1090	13	0.34
Maximum length (m)	30–50 (69)	759 ± 987	30–3520	13	0.32
Shape (0.0–1.0)	0.2–0.3 (23)	0.39 ± 0.22	0.04–0.80	13	0.16

* $P < 0.05$.

Table 6. Topographical characteristics measured from Crowned Hawk-Eagle nest and random trees in KwaZulu-Natal (N = 13 nests).

VARIABLES	NEST TREE	RANDOM TREE	U[a]
Distance to water (m)	83 ± 147 (10–550)[b]	159 ± 199 (10–520)	0.86
Distance to house (m)	859 ± 1661 (20–6250)	906 ± 1738 (20–6550)	0.24
Distance to road (m)	282 ± 277 (10–810)	285 ± 341 (30–1010)	0.11

[a] Mann-Whitney U-test.
[b] Mean ± 1 SD (range).

from nearby trees (Tuer and Tuer 1974, Kalina and Butynski 1994). This may be a reason why Crowned Hawk-Eagles often select emergents for nest sites, especially in Taï where eight diurnal monkey species are found at very high densities (McGraw 1998). In Taï, the tall nest trees with their wide bases and high, first side branches (mean = 34 m from the ground) may be extremely difficult, if not impossible, for monkeys to climb (T. Struhsaker pers. comm.). In KwaZulu-Natal, the presence of fewer primate species (three at the most; Smithers 1983) may have resulted in reduced predation risk for nestlings and might have allowed for the use of lower and non-emergent trees.

Sites may also be selected for nesting because the foliage protects the nest against adverse weather conditions (Moore and Henny 1983, Bosakowski and Speiser 1994). Crowned Hawk-Eagle nests are usually situated within the leafy canopy, but the birds also nest in exposed positions in partially collapsed or dead trees (Steyn 1982, Tarboton and Allan 1984, Kalina and Butynski 1994). In this study, 32 nests were located in or below the foliage and therefore sheltered, whereas the remaining three nests, two of which produced young during the study, were located in exposed positions in dead trees. Hence, although there was a trend for the birds to nest in a sheltered position, other factors, such as the availability of suitable nesting sites and the cost of building a new nest, probably influenced the continued occupation of a nest in a dying or dead tree.

Lastly, tree-nesting forest raptors may select trees for their size and structural features, such as a tall and open canopy, that allow unobstructed access to the nest (Speiser and Bosakowski 1987, Cerasoli and Penteriani 1996). The Crowned Hawk-Eagle may require a nest that is easily accessible as it needs to fly to the nest carrying sticks up to 1.2 m long and 8 cm thick (Steyn 1982). In addition, Crowned Hawk-Eagles are capable of killing prey 3–4 times their body mass, such as bushbuck (*Tragelaphus scriptus*; Daneel 1979), which they dismember and carry in parts to the nest. Brown (1966) noted that, in the Karen Forest in Kenya, these approach flights were always above the canopy, very laborious and broken into short 91–137 m stints so as to rest between flights. Under these conditions, access to the nest would be critical in order to deliver nesting material and prey to the nest. Nesting above the forest canopy in an emergent tree enhances accessibility.

The large indigenous nest trees were simple in structure and provided, on average, one central fork, 3–4 forks against the main branch and 3–5 forks on side branches for the eagles to place their nest. Notwithstanding, only 2–4 branches were used on which to build these large nests, indicating that big, primary and secondary forks were selected and not the smaller, multi-stemmed forks from within the canopy structure. Large raptors require a large tree-fork (crotch) to place the nest in and the more open branch structure may facilitate access (Newton 1979). The exotic eucalyptus differed from the indigenous nest trees in that they provided, on average, 11 more forks. This was largely due to the single main-stem growth form of these commercially-cultivated trees. Trees from these stands were also largely of similar height, probably because trees in these single species stands were planted simultaneously. As seven of eight non-emergent, eucalyptus nest trees were located on the edge of the nest stand, the eagles may circumvent the scarcity of emergent eucalyptus by selecting edge trees that have greater access to the nest.

In conclusion, because nests located within and above the canopy were equally accessible, access seemed to be the most critical feature identifying a Crowned Hawk-Eagle nesting tree and site. The findings that indigenous nest trees in KwaZulu-Natal did not differ from eucalyptus or indigenous trees from Taï Forest in terms of tree density and central and side fork availability, may indicate that indigenous trees with their multiple main stems and open branch structure may be as accessible for flying eagles as emergent or edge trees.

This study did not quantify the 'openness' and accessibility of indigenous nest trees in KwaZulu-Natal, particularly with regard to tree canopy diameter and volume, branch spacing and diameter, and branch angle as nests were often placed on near horizontal branches. Also, we did not examine the inter-relationship between the largest-diameter side branches (required to support the large nests) and the position of the primary and secondary forks below or just inside the foliage, related to openness and improved access. We also did not take into account the slope at the nest site and aspect of the nest, as nests located on the downhill side of the tree may have been more accessible to flying eagles. Given the floristic differences between forests in Taï and KwaZulu-Natal, a comparison of nest sites with randomly selected sites, conducted at each nest stand, would have further contributed toward the understanding of what constitutes a suitable nest tree. Lastly, data on how easy arboreal primates can climb nest trees, particularly from the base, would have added to our understanding of how successful Crowned Hawk-Eagles are in eliminating the predation risk by nesting in tall, emergent trees.

Recommendations. Wildlife managers need to manage forests by balancing timber harvesting with maintaining wildlife habitat and must employ multi-resource plans to do so (Lilieholm et al. 1993, Vermeulen 1999, Malan and Robinson 2001). These plans should incorporate both practical and proactive management objectives to conserve nesting habitat for large eagles in exotic and indigenous forests. Apart from silvicultural guidelines, other considerations must include the proximity of nests to hunting habitat, their temporal and spatial distribution, and the effects of human disturbance on nesting eagles (Lilieholm et al. 1993).

In this study, because we could not obtain reliable data on the age of the nests and how many young were fledged from each nest over time, we did not compare the structural features of productive between unproductive nests. Although other factors also influence productivity, e.g., experience of breeders, prey abundance, and persecution rates, the productivity analysis may have highlighted subtle differences between suitable and unsuitable nest trees and nest-placement sites. Our recommendations should therefore be treated with some caution, as nests included in this study might have been found unsuitable on the long term because certain deficient nest features may have limited successful reproduction.

Nonetheless, the nest trees must have open-branch structures and large tree-forks. As nest trees are typically emergents or edge trees, these trees can be cultivated by felling surrounding trees or leaving the tall trees standing (Seydack 1995). In this study more than half of the Crowned Hawk-Eagle nests were positioned in a central fork, therefore, the techniques of coppice-reduction or selective pruning could be employed to cultivate a tree with the preferred 2–4 main branches. As Brown (1966) demonstrated, suitable nest trees can be identified *a priori*, and managers can therefore implement these techniques to ensure a continued supply of suitable nest trees.

To qualify as a nest tree, commercial eucalyptus should be managed to reach a minimum height of 34 m and DBH of 83 cm (i.e., minimum size selected for nesting). Indigenous trees selected must attain a minimum height of 15 m and diameter of 35 cm. The mean stand density of 156 trees/ha can be employed as a guideline for Crowned Hawk-Eagle nesting habitat. Although exotic stands must be managed to a minimum size so as not to encroach onto indigenous vegetation, nest-tree stand size itself is nonessential. Furthermore, in plantations, nest stands cannot be placed at random as raptors often require nest trees to be located away from certain topographical features (Andrew and Mosher 1982, Malan and Robinson 1999). However, with regard to the proximity of nests to human dwellings, water bodies, and public roads, the Crowned Hawk-Eagles of KwaZulu-Natal were remarkably non-selective and tolerant. In fact, the city of Durban, located in this province, harbors 12 active nests within its metropolitan boundaries. Inter-stand distances were not recorded in this study, but Crowned Hawk-Eagles are known to nest 1.8–4.0 km apart and, thus, require only a relatively small patch of suitable hunting habitat (Tarboton and Allan 1984, Allan et al. 1996, Mitani et al. 2001, Shultz 2002). Given the size of some of the prey these eagles hunt, nest stands must preferentially be located near the hunting habitat so as to shorten flight distances to the nest.

Because Crowned Hawk-Eagles use the same nest for 10 years or longer, often until the tree collapses (Brown 1966, Steyn 1982), suitable trees should not be felled. If the nest stand or tree must be harvested, the felling should be done outside the birds' breeding season (August–March) and 6–12 months after the nestlings have fledged to allow sufficient time for the young bird to become independent (Steyn 1982, Tarboton and Allan 1984). Given that a nest takes 4–5 mo to build (Brown 1966), replacement nest trees, located in the vicinity of the nest tree in use, should be cultivated long in advance to provide a suitable alternative nest.

The Crowned Hawk-Eagle in South Africa has been classified as near threatened because of past exploitation of nest trees and the likely destruction of nesting habitat in the near future (Boshoff et al. 1983, Barnes 2000). Occupied nests should be closely monitored to assess the status of this species and to collect data on what constitutes productive nests. Large tree-nesting forest raptors will always have few suitable trees to nest in as large trees and forks are less abundant than smaller ones (Newton 1979). When nesting in large trees, eagles also compete directly with humans for this scarce resource (Boshoff et al. 1983, Watson and Rabarisoa 2000). It is, therefore, no longer adequate simply to protect forests for birds of conservation concern, but specific efforts must be made to satisfy the nesting requirements of the Crowned Hawk-Eagle and other tree-nesting forest raptors; e.g., in South Africa the Bat Hawk (*Macheiramphus alcinus*), Ayres's Hawk-Eagle (*Hieraaetus ayresii*), and Fasciated Snake-Eagle (*Circaetus fasciolatus*) (Barnes 2000, Malan and Marais in press). Ultimately, a species-specific management plan should be developed for these and other tree-nesting forest birds and the maintenance of nest-tree structural and topographical features incorporated into management decisions.

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